INSPECTOR'S HANDBOOK

OF

REINFORCED CONCRETE

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PREFACE

WITH the strides made in the past few years in the reinforced concrete building construction, the demand for inspectors or clerks of the works having experience in this construction has been far greater than the supply. Those architects or engineers who have specialized in this construction have had applications from inspectors continually who wish to avail themselves of contact with this work under the direction of specialists. The authors' experience in selecting men to represent their firm in this capacity has led them to publish this little volume with the hope that it would fill a place in the literature on reinforced concrete not covered by existing books. Personal contact with the inspectors and their viewpoint of various details of the work convince us of the necessity of such a book of instruction. While not endeavoring to inform the inspector of all his duties, this volume is written to point out the essentials governing the construction of this class of buildings.

For the sake of simplicity in treating the subject of reinforced concrete, we shall divide it into three general divisions, each division embracing a study of one of the main elements that enter into the

construction of reinforced concrete. These are, first, the "Forms or Falsework," second, the "Reinforcement," and third, the "Concrete." The chapters will follow in the order named, as it is the intention to follow throughout the book the process of construction of the actual work as nearly as can be. In addition we have added an appendix embracing formulas and tables to be used in calculating the strength of reinforced concrete.

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CHAPTER I

FORMS OR FALSEWORK

As the function of the forms is to secure a suitable receptacle in which to mold the concrete, it is of greatest importance that they should be constructed with the utmost care. Many designers leave the details of the construction of these forms to the contractor, working on the supposition that if the specifications require a certain standard of work when finished, the contractor will use his best efforts to secure this result. Such a supposition is far from being the case, for the contractor usually will take greater chances during the construction than is always good for the work. Experienced contractors generally do exercise thought in constructing the forms, so that the results of the finished work may be very satisfactory; however, the greatest vigilance is required of the inspector to see that the forms are properly constructed, no matter who is doing the work.

It is presumed that the inspector understands the method of constructing forms, but to bring out more strongly the essential points to be looked after, a brief description of the various types used for floors and roofs in common use will be given.

In thinking of concrete, it must be viewed in the

light of a plastic material and not one of a fixed rigid nature, such as we are accustomed to picture to our minds when dealing with natural materials like stone and wood. Having, then, this point of view, it naturally follows that the material will take the shape or form prescribed by the molds or falsework into which it is poured. These forms, then, at once become the important medium for making concrete, and too much study cannot be given to this part of the work.

Box-shaped Forms.—Inverted boxes with the sides made with a draw form a common method of constructing this type of forms. These may be made to fit an entire panel if it is not too large for convenience of handling, for in all form work, this feature is one which has to be considered. The ease with which such forms can be taken down and carried to another floor and reset is one of the determining factors of their use, aside from the fact of there being a number of stories of similar design and size. If the forms are not made with the sides on a splay, it will be difficult to drop them, as the concrete is very apt to adhere to the box so as to make the task of removing the forms as a unit almost an impossibility; hence, if the design of the beams and girders shows these members with plumb sides, a slight deviation from the design would be necessary with this type of forms. The side of the forms should project down past the edges of the bottom of the beam and girder forms, to permit the bottom plank to remain in place while the boxes are being removed.

Knock-Down Forms.—The common method of constructing forms is to build up a falsework with individual planks cleated together for the sides of beams and girders, as well as separate boards for the lagging for the slabs, where the construction consists of girders, beams, and slabs. Of course, where there are few beams and the construction consists of long span slabs or of concrete joists with tile filling between, the construction of the forms is a very simple matter, as there is very little boxing; the important feature of the construction then consists of the proper support of the flat lagging by means of shores or props.

When knock-down forms are used for beams and girder construction, the important point for the inspector to watch is that their construction is such as to permit of the lagging under slabs and the sides of beams and girders being removed without disturbing the bottom of the beams and girders and their corresponding props or supports, for it is always an advantage to have these parts of the concrete stripped and exposed before removing the shores, as the forms may be used on another floor much sooner if this method is employed without endangering the safety of the new concrete. Many serious accidents have been attributed to the premature removal of props or shores.

Props or Shores.—Too much stress cannot be placed upon the importance of having an ample number of props or shores under the forms to hold them rigid and secure while the concrete is being placed, and to be so placed as to prevent sagging of the beams

and girders before the concrete has hardened; many unsightly pieces of work have been performed due to lack of proper regard for this essential. Usually 4×4 or 3×4 inch pieces are set under centers of beams, and girders varying from three to five feet apart, according to the spacing of the beams and weight of the concrete to be put in the forms, also the thickness of the beam bottoms should be such as to prevent sagging between shores, as much nailing of sides of beam forms to bottoms is not advisable; in fact, if the form could be constructed so that the joints which have to come apart, when forms are struck, were without nails, the case of striking the forms would be much increased and less damage to the forms as well as concrete result. When the props supporting the first tier or story rest on the ground, it is a very difficult matter to maintain a strictly level floor, due to the shores sinking in the ground when softened by rains, or in cases where the ground is of a yielding nature; in such case it is best to truss from props set on the column footings, and run jack trusses from these to support the forms above, thus avoiding any settlement of the forms due to improper foundations.

Trusses should also be used where it is desired to hasten the laying of the finished floor, especially the ground floor for the trenches can be dug for pipes, etc., without having to wait two weeks or more to remove the props which would be in the way of the work.

All props under forms should be braced at right angles in both directions, once in the height if the story is not exceedingly high, with 1×6 inch leger

boards set about six feet from the floor, to give headroom to workmen on the floor; leger boards should also be run at the top of the studs in one direction at right angles to the beam forms, and the sides of the beams wedged up on them; all studs should be wedged up tight at bottom and top.

Slab forms should be braced or supported at intervals of from two to three feet apart with 3×4 or 2×6 inch beams resting on cleats on the sides of the beam forms. Sufficient diagonal bracing should be introduced between the columns and studs as well as between beams, to prevent racking over of the forms. The inspector should be very particular to see, before any concrete is poured, that all forms are secured. Should the beams be over eight feet apart, it may be necessary to introduce props under the lagging or forms of the slab unless the props under beams are made extra heavy and the cross beams under lagging designed for the extra long span.

Steel Beam Girders.—In some instances steel beams act as girders for the support of concrete beams, and the forms must be hung to these beams; in such cases long bolts or rods can be hung over the steel beams and extend below the bottom flange sufficiently far to permit of a heavy stringer running parallel to the steel beams to be secured thereto, and act as a secondary beam or support for the forms of the concrete beams. Whatever method is employed, all parts should figure strong enough to carry all loads coming upon them, the same as if they formed a permanent construction.

A very good system to employ in constructing forms is to have the lagging for slabs made up of 1×6 inch tongued and grooved boards battened on the under side, forming panels made in sections that can be readily handled without taking apart; also, the sides of beams and girders can be made up of two planks or whatever number is required to make the depth, and these be battened together so that each side can be handled as one piece.

Of course, there is more or less damage caused each time a set of forms is used, and before pouring the concrete after the forms are again reset, the concrete adhering to the surface should be scraped off and the boards left perfectly smooth, and wide joints should be filled up with strips of wood or strips of waterproof paper should be tacked over the joints, care being taken to make the forms as tight as possible, to keep the liquid concrete from running out. It is not necessary to oil forms, although some contractors prefer to coat the wood with a light oil to prevent any concrete adhering to the forms.

The thickness of the lumber for the sides of beams and girders should not be less than 1½ inch; usually a cheap grade of wood is used, such as sap pine. The bottom of beams and girders should be 2-inch material; the lagging of slabs should be 1½ inch thick, but it can be as light as ¾-inch if the boards are narrow, say not over six inches wide, and tongued and grooved together. All lumber should be planed on the side next to the concrete; this permits the forms to be removed much more easily. Chamfers should occur

on the bottom edge of all beams and girders and in the ceiling angle to prevent spalling off of the corners when removing forms, as the custom of using small crow bars to force the forms off the concrete is likely to break off corners.

Column Forms.—As columns are usually filled in one operation, the forms should be built with the $1\frac{1}{2}$ inch plank run vertically, having wood collars extending around the four sides; the collars should be very substantial and closer together at the bottom than at the top, due to the hydrostatic pressure of the wet concrete tending to burst the forms; there is a common fault among contractors to skimp on the number of collars.

Loose hand-hole caps should be provided at the base of all columns sufficiently large to gain access to the inside of the form at the bottom of the column to adjust the column rods and remove shaving chips, dirt, etc., that collect in the columns; these should be cleaned out just before concreting.

Similar hand-hole caps should be provided in the bottom of all girders in a bay to permit of the cleaning out of the chips, etc., when the forms are flushed with water just before concreting. It is the care exercised in just such points that results in securing work which is first-class in every particular, for it must be remembered that concrete once cast cannot be repaired without taking out an entire member or section of a floor, so that it becomes a very serious matter. Attention to details will obviate the necessity for such a procedure. All columns, if square, should

likewise be chamfered by placing triangular pieces vertically in the corners of the column forms. The chamfers should run the full length of the columns.

Wrought iron clamps are very frequently used in place of extra nailing on the bottom edge of beams and girders and sometimes on columns, but it is more usual on columns where it is desired not to trust the nails in the collars, to use bolts to hold the two collars on opposite sides of the columns together.

Round columns are usually made by assembling narrow boards or staves. shaped to suit the radius of the column, or with straight faces, run vertically, and banding them with wrought iron flat bands made in halves and bolted together, or with wood collars bolted together. If the columns are all of one diameter, and there are a number of them, a better plan is to make the forms of heavy galvanized sheet iron banded together, in which case the metal must be soaped or oiled to prevent the concrete from adhering to the metal.

Cleaning.—All wood forms should be thoroughly cleaned and drenched with water before depositing concrete, and in very warm, sunny weather, should be kept constantly wet to prevent excessive shrinkage and warping. In high buildings, where the water pressure is not sufficient to bring the water to the upper stories, it is necessary to instal a pump for the purpose. Usually a steam pump is employed driven by steam from the hoisting engine boiler.

Wall Forms.—The construction of forms for walls,

while not involving the complex carpenter work demanded by floors with beams and girders, do require great care in providing sufficient bracing to maintain the forms plumb and true to line. The inspector should be very diligent to see that proper precautions are taken to insure the forms remaining straight and true when the concrete is poured. Some device must be provided to prevent the forms from bulging and at the same time keep them the proper distance apart. One and one-half inch stuff should be used for walls, with 3×4 or 3×6 inch vertical upright on each side, spaced not over three feet centers. A good method of constructing the forms is to make large panels of tongued and grooved boards, as outlined for slabs. The panels can be re-used over and over again if the wall is solid and extensive. The uprights should be prevented from spreading by means of bolts running through the walls, or, as is sometimes the case, by No. 10 wire loops extended around the uprights on both sides of the wall and twisted within the body of the wall to hold the forms tight up against spreaders placed between the forms. These spreaders must be removed when the concrete fills the forms where they occur. A good form of spreader consists of a concrete block about four inches square of a length equal to the thickness of the wall, with a hole through its center of a size to accommodate the bolts with which the forms are bolted together. These blocks are made in advance of being used and allowed to set hard. When the forms are removed the holes are filled on each side with cement mortar.

If the wall is not too high, the blocks need not be closer than three feet in each direction. When interior partitions are made of monolithic concrete, this method of keeping the forms apart is preferred to any other.

The uprights holding the forms should be braced horizontally by running a horizontal stringer piece the full length of the wall and bracing it to some substantial support to keep the wall in line. Where walls occur below grade and act as retaining walls, the sheet piling, if any is used, is generally used as the outside form and allowed to remain after the concrete is poured. A wall of this sort cannot be poured the entire height at one time, as there are horizontal stringer pieces braced to the ground to hold the sheet piling against the bank; in such cases the forms are filled to a little below the bottom of the stringer, and after the conerete has hardened, another stringer is placed on the outside of the forms of the retaining wall where it has been filled and new braces introduced, being wedged up to take the thrust on the wall, when the orginal stringer and braces can be removed and the rest of the wall cast. This method of filling retaining walls removes any danger of the thrust of the bank shifting the forms.

Wall Bearings.—If brick or stone walls form the support of the concrete floor, the bearings for beams and girders should be at least 9 inches deep and the pocket made dove-tail shape on the side to increase the anchorage of the beam to the wall. This also increases the bearing area of the end of

the beam, which is of advantage if it is heavily loaded.

Pipe Holes, Sleeves, etc.—These should be provided in the forms located to suit each individual case. The plumber, steam-fitters, and electrician should locate their own openings, etc.

Removal of Forms.—A serious element of danger in reinforced concrete is the premature removal of the shores from under the forms; many accidents or failures of floors have been attributed to this cause, although other causes have contributed to the disasters, such as improper design and bad workmanship. Too much stress cannot be placed upon the importance of permitting the props to remain under the concrete a length of time sufficient to insure against failure. As mentioned above, this is accomplished by constructing the forms so that all the wood lagging under slabs and the sides of beams and girders can be removed without disturbing the props under the bottom of the beams and girders. The temptation for the contractor, if the work is of any magnitude, is to remove the forms as soon as he needs them for another floor, and thus take chances of producing a failure; the inspector cannot be too strict in insisting upon the props remaining in position until the concrete has hardened sufficienty beyond a doubt.

In summer weather with normal conditions, it is safe to remove the lagging or forms from under slabs in one week's time after the pouring of the concrete. Of course, the beam and girder sides (but not bottoms) can be removed likewise; this permits the

drying of the concrete much faster and expedites the work.

Shores or props under conditions cited above, should remain in place two weeks after the concrete is poured; if the span is very long, say forty to fifty feet, and the beams or girders heavy, this length of time should be increased. In spring and fall, when the weather is damp and chilly, it may be necessary to leave the forms and props much longer than cited above. It is far better to lose a few days at this stage of the construction than to jeopardize the safety of the building by undue haste.

In freezing weather, it may be necessary to leave the props under the concrete work two or three months, or even longer, if the concrete has frozen and not obtained its natural set. In order to determine this point, the best course for the inspector to pursue is to break a small piece of concrete out of the work and take it to a warm place and leave it long enough to determine whether it has obtained its natural set by noticing whether it becomes soft and moist due to thawing of the frozen water in the concrete; this will be self-evident, and is a sure test of whether the concrete is frozen or set. If frozen, the forms should remain until the concrete has thawed out and set naturally under the warmer weather.

In warm weather the test to determine whether the concrete is set, is to srike it with an iron bar or hammer; the concrete should ring under the blow if it has a hard set. Of course, it is not necessary that it should test up in two weeks as hard as if it

were six months old; the experience of the inspector will determine where the point of safety lies.

In summing up, the inspector should take no chances, and should not be governed by the desire of the contractor or owner to push the work beyond safe lines.

CHAPTER II

REINFORCEMENT

Systems and Bars.—It is not in the province of this little volume to rehearse the history of reinforced concrete, and the development of the numerous types of construction and systems now in use. If the reader is interested in this phase of the subject, he can obtain the information from almost any of the standard books now published on the subject of Reinforced Concrete.

A brief summary, however, of the systems which the inspector is most likely to come in contact with, and the manner of placing the reinforcing metal is appropos of the scope of this work. The use of the word "system" in this volume is restricted to the reinforcement and is not intended to apply to types of concrete construction. All systems can be grouped under three main classes, varying from each other in some fundamental.

The first group consists of the loose bar systems in which the reinforcing elements are separate bars or rods, whether plain or deformed.

The second group consists of built-up frames making a number of bars into a unit and placing them in the mold as such.

The third group consists of molding the beams and girders in advance on the ground, permitting them to harden and then to erect them in much the same manner as steel or wooden beams are erected. This last system has not as yet been very widely employed. The Edison Portland Cement Co. has used this system in a mill building built for themselves; they call the system "Separately Molded Members."

It is seen that the shape of the bar in the above classification does not influence the grouping of the system. It is the writers' belief that the use of the word "system" has been misused by being applied to a form of bars instead of to a method of applying bars for the purpose of reinforcing concrete.

Each of the above classes or groups can be subdivided into variations from the general type; also, there are combinations of structural steel shapes with concrete which could be classed in a separate group, but it was thought best not to confuse strictly reinforced concrete systems with any combination of the two.

Loose Bars.—The most popular system, if it may be called such, as it does not seem to be worthy of the name, is the use of separate and individual bars for the reinforcing of beams, girders, slabs, columns, walls, etc. This consists of placing in the mold or form each piece of reinforcement as a separate unit without any mechanical union to its neighboring piece. A little reflection will plainly show that the practical difficulties encountered in constructing work in this manner make the system the least reliable of any, as

it is possible to have the bars misplaced and even forgotten should the workmen be unskilful and left to themselves, as very frequently happens if the foreman is obliged to look after more than one part of the work. If the inspector has charge of work when such a system is employed, he should insist on having the reinforcement stacked in racks with separate compartments for the various sizes, so as to keep each size separated from the others, and to have the contractor place in position all the reinforcement for a certain section of the floor before any concreting is performed. This will give the inspector an opportunity to inspect a section of the work in its entirety and not piecemeal, as by the latter method, should the inspector call the contractor's attention to bars not being in place, he is very apt to be assured by the foreman that the bars will be in before any concrete is poured, and if, by chance, the inspector was on another part of the work when the concrete was poured, he would be at a loss to know whether his instructions were carried out. Also, it very frequently happens that work is performed overtime when the inspector may not have an opportunity to be on hand. The writers' experience has proven that this system of reinforced concrete is the least desirable and the most difficult to superintend.

✓ If loose bars must be used, the reinforcing elements should be wired together to insure their being in place.

Unit Systems.—As the name implies, this system consists in building up the reinforcing bars into a frame, each principal member being built into a unit either in

a shop or on the ground, by men skilled in the work; each frame having a shop mark corresponding to the mark on a carefully prepared erection diagram. It will be seen that this system eliminates, on the building, the necessity of building up the bars into frames for each beam or girder. All the workmen at the building are obliged to do is to set the frame, as delivered, in the mold prepared for it. The inspector is also given a chance to check up, in advance of the frames being set in place, the sizes and numbers of bars, and pass on the work days in advance of their use, in the construction. In this way, mistakes can be readily detected, and when the frame is in place, the inspector has no further worry as to whether all the bars are in position.

Several types of these frames are on the market, each possessing special details to carry out some special feature restricted to the system.

Under this class may also be included webbing or expanded metal used for slabs and walls. These are practically a number of small reinforcing bars united together. While the slab is not as important a part of a floor system as beams and girders, the use of a webbing for reinforcing the slab is to be preferred, as the spacing of the bars is not deranged by workmen disturbing the sheet of metal, as occurs when separate bars are used in the slabs.

The molding of concrete beams and girders in advance on the ground and erecting them upon supports requires heavy lifting apparatus and also has the disadvantage that the building erected with such a sys-

tem lacks the monolithic feature of a system in which the concrete is cast in the position it is to occupy in the building. The advantage of being able to reject a member that is improperly built is a very good feature of the system, and in special cases, this system is to be preferred to the more common method, especially for lintels in connection with brick walls where the lintel does not form part of a floor system, and is to have a dressed face or scrubbed finish.

The use of I-beams of small size for the reinforcing element of beams and girders, but of sufficient strength to carry the dead weight of the floor without the use of shores or props, is a very desirable system where the floor space must be left unobstructed during the erection of the building.

As it is undesirable to depend on the adhesion of concrete to a large plain surface of metal, the use of stirrups riveted to the beams should be insisted upon.

In order to secure level flat ceilings in such buildings as hotels, residences, etc., the combination of terra cotta tile or plaster blocks as a filling between small concrete beams which are spaced about sixteen inches on centers, forms an admirable construction, provided other details of construction are complied with and that no dependence is placed on the tile to assist the concrete to resist the compression forces, sufficient thickness of slab being provided over the tile to meet this condition.

The point where a concrete slab will have to be provided of a thickness in excess of what is required

over the small beams is over the main girders, and care must be exercised to see that the slab is built integral with the girder, no matter what system of reinforcement is used.

Plain Bars.—The use of plain bars for reinforcing concrete seems to have found favor in Europe to the exclusion of almost any other type, principally on account of the universal rolling of round and square bars, which make them more readily obtainable and in general answer the purpose. Their use, in the writers' opinion, should be restricted to such work where the loads are quiescent, as there is danger of the bond between the concrete and steel being broken if the construction is subjected to shocks. In important members, hook ends should be used on the bars to assist in preventing slipping of the bars; also, when plain bars are used, they should lap much further than if deformed bars are used.

Deformed Bars.—In the United States, practice seems to favor the use of deformed bars. There are a number of patented bars on the market all calculated to increase the bond between the steel and the concrete. In figuring the area of these bars, net sections should only be considered, as it is very seldom that the projections add to the area of the bars. Cold twisted square bars are much used and constitute one of the best forms of bars. High carbon deformed steel bars on account of their high elastic limit, when made from original billets and not from old rails, are equal to cold twisted bars and can be used with safety.

The trussed or Kahn bars has the double feature of being a deformed bar, as well as providing some stirrup for the web reinforcement of the beam.

The use of expanded metal and webbing, or fabric, consisting of main wires and secondary wires at right angles to the principal wires are, in effect, deformed bars, the difference being that there are a number of them assembled together.

In girder frames with the stirrups shrunk on or otherwise rigidly attached to the main bars, the adhesion is so much increased as to bring this type under the head of deformed bars.

Cables.—The use of cables for reinforcing beams and girders is not considered practical, although there is one system on the market which advocated its use. The writers cannot see any advantage gained in the use of cables for beams and girders and decided disadvantage is apparent, as the cable to be effective should be drawn up tight, which is not practicable in beam and girder construction. For slabs in connection with a webbing, cables may be successfully used, but they will be of little value unless drawn up taut.

Placing Reinforcement.—The most important duty of the inspector is to see that all steel reinforcing bars are placed and maintained in their proper position. With some systems this is comparatively an easy task, while with the loose-bar system, it is practically impossible of accomplishment. When the bars are made up into a frame, this is placed as a unit in the forms and maintained in its proper position by a socket and locking device, or prongs projecting down

from the bars to keep the rods away from the bottom of the mold. The point to observe in setting frames is to see that the frame corresponds to the detail for the particular beam or girder for which it is intended. Sometimes a beam or girder is made up of more than one frame. In the original "Unit" system, frequently two frames were used in a beam consisting of a bottom and a top frame; in another type of frame construction, the "pin-connected" frame, a beam is made up of a number of frames composed of two bars each, the frames being placed side by side.

Still another variation of the unit system consists in a collapsible stirrup frame so constructed as to form a basket to hold the main reinforcing bars. The stirrup frame is placed in the mold first, being hung by means of the stirrups. The main bars are then placed in the stirrup frame and held in place by metal spacers.

As these systems are patented, the manufacturers provide all the data for installing or setting their frames, and the inspector should see that the reinforcement is placed accordingly.

When frames are not used for beams and girders, successful results can be obtained by wiring the main bars together and letting the stirrups act as hangers to suspend the bars in the mold. This is accomplished by having the stirrup made U-shaped with hook ends turned down at an incline, the length of the hook being sufficient to permit the stirrup to rest on the top of the slab form. The further advantage of the hook is in its forming an anchorage in the con-

crete on the slab, thereby increasing the bond between the beam and the slab.

The hook ends of the stirrups should lap over the slab reinforcement, or a one-quarter inch rod should run parallel to the beam in the eye formed by the top of hook, so as to weave, so to speak, the slab reinforcement to the vertical reinforcement of the beams, which is the stirrups. This will prevent the slab from shearing off from the beam, which it is very apt to do where one day's work joins another. Where a webbing or mesh is used for the slab reinforcement, the stirrups should be long enough to hook over the wires of the mesh.

Too much care cannot be exercised in having sufficient lap where the rods make a joint, whether it be in columns at the story levels, or in girders and beams over supports, or in the slab.

Frequently the bars of beams only extend at each end, where they rest on girders, sufficiently far to secure a good bearing, which is as far as the other side of the girder for the top bars. In these cases, tie rods about five feet in length should be placed in the slab over the joint, the number and size of the bars depending on the load on the girder and its size.

These tie-rods should be placed at the end of a beam where framed into a girder, even if on the opposite side of the girder, the beam does not occur; in this case, one-half the tie-rod would be over the top of the beam and the other half in the adjoining slab.

Another important detail to remember is that the

bottom bars of beams should rest on top or pass over the bottom bars of the girder.

Some engineers wire the rods together where they lap, assuming that the joint is more efficient. The advantage of doing this is questionable, as it is difficult to have the wiring made as tight as it should be to develop any strength. The better plan, it would seem, would be to give ample lap of the bars and depend on the concrete transmitting the stress to the rods. Of course, in the case of deformed bars, if the wiring is thoroughly done, an increase in the efficiency of the joint would result, from the fact that the projections of the bars would tend to interlock, thereby preventing slipping of the rods as soon as in the case of no wiring.

Welding of Bars.—In very long beams, it frequently occurs that stock bars are too short to extend the full length of the beam; in such cases welding of two bars together is resorted to. If welding is necessary, the joint should be near the ends and not near the midde of the beam. This will require two welds instead of one, but the inspector should insist on the welding being done in this manner; the reason for this is very evident, since in most beams the greatest bending moment is at or near the middle of the span, the bars should have the greatest strength at this point; near the ends of the beam the bending moment becomes less, and consequently the joints should be located accordingly.

For very long spans, such as arches of bridges, continuous rods can be obtained by using turnbuckles

screwed to the ends of adjacent bars. This method can also be used for beams in place of welding if there is sufficient space for the turnbuckles.

Function of the Various Parts of the Reinforcement.— As the intelligent supervision of any form of construction depends on the inspector's knowledge of the principles of the construction, as well as the mechanical resultsdesired, it is thought that an explanation of the function performed by the various reinforcing elements would not be amiss here.

In any simple beam, the top is in compression and the bottom in tension, hence it is that the rods must be placed near the bottom; as reinforced concrete is monolithic in character the ends of the beams become restrained or, as it were, anchored to the supports, so that a reversal of stresses takes place near the supports and tension is developed at the top of the beam and compression in the bottom at these places. In order to resist these tensile stresses in the top of the beam, some of the main bars can be turned up at an incline and bent horizontally at the top of the beams, or extra straight rods can be introduced in the top of the beam extending from the support into the beam for a distance of at least one-quarter of the span. If the bars are bent up, usually one-half of those in the bottom run straight through and the other half are trussed, as mentioned above. In case an odd number of bars are used the greater number should be trussed.

Where beams are continuous, these trussed rods can run into the next span a short distance and over-

lap with the corresponding trussed rods from the abutting beam, or if separate straight rods are used in the top of the beams, they should be double the length required for one beam and project half way into each beam. Where the trussed rods stop over the girder, separate tie-rods should connect both beams, as mentioned heretofore.

Stirrups.—The stirrups are called web reinforcement because they act in transferring stress vertically from top to bottom of the beam. While it is not always necessary to use stirrups to resist the shearing stresses, the concrete being in many cases sufficient for the purpose, it is necessary to use them spaced throughout the beam to make a metallic union between the slab and the beam. Where the floor has beams, girders and slabs, as is usual in most buildings, notwithstanding the slab is cast or poured the same day as the beams, shrinkage of the concrete is apt to part the slab from the beam if there is not some means to hold the two together mechanically; accidents to floors have resulted from this cause.

Where a day's work joins another day's work over a beam or girder, one-half of the ends of the stirrups should be left uncovered and project into the fresh concrete of the next day, and the slab rods from the previous day's work should project at least twelve inches into the next section of the slab; the rods in the section of the slab to be put down the next day should run under the hooks of the stirrups to make a secure bond.

Very frequently additional hair-pin stirrups made

of five-sixteenth round iron twelve inches long are pushed down into the fresh concrete of the beam and left to project sufficiently far to permit of slab rods of the section put in the next day to thread under their loops, putting the stirrups as close as twelve inches on centers or thereabouts. This is often resorted to should there be any reason whatever why it would be impossible to lay the slab over all the beams the same day.

Where diagonal tension or horizontal shear exists in the beams in excess of the safe shearing resistance of the concrete, the stirrup must be figured to take up an amount of shear sufficient to reduce the shearing stress upon the concrete to the safe limits; whether the stirrups are set vertical or on an incline diverging towards the center of the span is immaterial, as very successful results have been obtained by both methods.

Sockets, etc.—Some provision is usually made in concrete floors for the support of overhead fixtures. If a manufacturing building, usually sockets for the support of shafting are built in the beams; also small sockets for the support of the conduits for electric wire are sometimes built in the bottom of the slab, and short pieces of pipe are set in top of the beams and girders to permit the conduits to pass through the beams. All such devices should be accurately located according to detail drawing, and care exercised that the liquid cement does not enter the holes of sockets, etc.

CHAPTER III

CONCRETE

THE ingredients composing the concrete used in reinforced concrete construction should consist of Portland cement, sand and broken stone, or a mixture of Portland cement and graded gravel from fine to three-quarters of an inch size.

The use of concrete in which cinders or slag form part of the aggregate should not be employed for reinforced concrete beams, girders, or columns; concretes in which the above materials are used can with safety be employed for filling between steel beams and for fireproofing steel or iron columns, and for a concrete fill on top of reinforced concrete floors and roof slabs. The materials used in the concrete should be the best obtainable, and the inspector should be constantly on his guard to see that the quality is maintained, as it very frequently happens, due to the demand for materials, that stone is received for one operation from several different quarries, this course being necessary in order to obtain materials in sufficient quantities to keep the work going on uninterruptedly.

Cement.—Of all the material that go to make up a reinforced concrete structure, none is of such vital importance to the ultimate safety of the building as the cement, and none should receive such careful scrutiny as to its fitness. Happily we need not fear

for any trouble from this source if we only take the trouble to secure a high-grade Portland cement, as there are many brands now manufactured in this country which meet all the requirements for this class of work. Of course, natural or Rosendale cements should not be used for reinforced concrete, neither should slag cements until more experience has been gained with the use of this cement.

It is poor economy to attempt to save the cement in a reinforced concrete structure, and it is one of the things that if skimped is likely to result in a failure sooner than any other cause, with the exception possibly of premature removal of shores.

If a standard brand of high-grade Portland cement is used, it is almost safe to use the cement without test, except as to the accelerated or boiling test, but it is the part of wisdom not to permit any cement to be used until it has passed the tests recommended by the American Society for Testing Materials.

Sand.—Where the concrete is composed of cement, sand, and broken stone, the sand should be a washed sand or a clean, sharp bank sand free from loam and mica, consisting of grains graded from coarse to fine, not exceeding one-quarter of an inch in diameter; a small percentage of foreign ingredients, such as loam, clay, or dirt, in an amount not greater than five per cent by weight should not be objected to in the sand, as it is next to impossible to obtain a sand without such impurities.

The use of granulated stone as a substitute for sand is in accord with good practice, provided the quarry

dust is eliminated as the dust acts as an adulterant to the cement.

Where stone of the run of the crusher is used, excluding the stone dust, the quantity of sand used in the concrete should be lessened, as the smaller particles of stone act as sand; in all such cases an expert tester should be employed to determine the proportions of the various ingredients to make a perfect mix.

Stone and Gravel. — The strength and quality of the concrete depends to a large extent on the quality and size of the stone employed in the concrete.

Of course, the kind of the stone or gravel to be used in the structure is usually determined by local conditions; a stone that is available in one section of the country is not to be found in another section. Also, gravel may be found in large quantities and of the proper size to warrant its use over that of stone. However, tests seem to favor the use of trap rock as the best material for the aggregate, while granite also makes a good concrete.

For fireproof construction of the first class, soft limestone as the aggregate should not be employed, as under the action of fire and water it disintegrates; there may, however be some limestones which do not fail readily under the action of heat and water, and until it is determined by actual fire tests on the concrete made of this material, its use should be avoided.

For ordinary concrete, the stone or gravel should be of a size to pass through a one inch ring,and twenty-five per cent of the whole should not be more than one-half the maximum size. A denser, and hence a

stronger, concrete is obtained by the use of a stone graded in size from fine to coarse. For foundation work and thick walls, where the concrete is in bulk, stone of a size to pass a two inch ring will give satisfactory results.

Where there are a great number of bars located close together, it is better to use stone the maximum size of which is not over one-half of an inch.

Where the concrete is to be used for an exterior wall and to receive a surface treatment which will expose the stone, care must be exercised to see that the same kind and size of stone is used throughout the entire face of the wall, as the final appearance of the concrete may vary considerably should these precautions not be observed.

Proportions and Mixing.—In the matter of fixing the proportion of the concrete, the inspector has little to concern himself, as this is usually fixed by the specifications. With the actual mixing of the concrete to secure the specified proportion, the inspector has much to do. Should the quantity of concrete to be mixed be small, or should conditions at the site be such that a mechanical mixer cannot be installed immediately, hand mixing is permissible, in which case it is the inspector's duty to see that the ingredients that enter into each batch of concrete are measured in a box-like measure without bottom, containing a definite number of cubic feet; as the cement is usually delivered in sacks or bags containing one cubic foot, this material need not be measured. The sand and stone, however, should be measured in separate

measures, each built of a size to give the desired proportions, and to make a batch convenient for handling. For example, if the concrete is to be mixed in the proportions of one of cement, two of sand and four of broken stone, the box for the sand can be made of boards one foot high, nailed together to form the sides of a box 3 feet wide by 3 feet 4 inches long, inside dimensions. This will equal 10 cubic feet. The box for the stone should be the same height, but 4 feet wide by 5 feet long, which equals 20 cubic feet. To this quantity of sand and stone, 5 bags of cement should be added. This gives the proportions above stated, since 5 is ½ of 10 and ¼ of 20. This size batch may not be suitable for all parts of the work, but is here given to illustrate the principle of making the boxes.

Should it not be desired to make two boxes, a movable division can be put in the larger box, so located to give the required proportions.

Per Cent of Voids.—Should it be desirable to find the percentage of voids in either the sand or stone, a very good method is the following:

Fill a vessel containing one cubic foot with the stone or sand, then weigh the vessel so filled. Fill the same vessel without removing the stone with water until it comes flush with the top, then weigh again. Find the difference between the two weights, and divide this difference by the weight of a cubic foot of water, 62½ lbs., and the result will be the percentage of voids in stone or sand.

Hand Mixing.—In hand mixed concrete, the ingredients should be very thoroughly mixed; too much

importance can not be placed upon this feature of the work.

If the specifications do not state just how the hand mixing is to be performed, the inspector can use the following method, which has been found by practical experience to give very good results.

Upon a suitably built platform of wood, the sand and cement should be dumped and turned over twice dry, using shovels and rake (not a hoe). These materials can then be wetted and made into a mortar or left dry. The box measure for the stone should be set on the mortar after it is spread out and the box filled to the top with broken stone, the stone first being wet, then the whole mass should be again turned over with shovels and rake at least twice, adding water as the materials are being mixed to make a wet concrete. The water to be sprayed on the mixture with a hose to prevent the washing of the cement from the sand and stone. While experiments seem to show greater strength for concrete mixed dry, it is imperative in reinforced concrete that it be dense and surround every part of the steel reinforcement. This can only be secured by a copious use of water so that the concrete when poured in the mold will flow freely instead of having to depend upon subsequent tamping.

In work which the authors have supervised, they have noticed that the results are not so satisfactory when the concrete is mixed semi-dry as compared with a very wet mix. The danger of having honeycombed concrete is much greater with the drier mix.

The water used in the concrete should be clean and free from acids and other chemicals likely to affect the cement; if any doubt is entertained as to the purity of the water, a chemical test should be made.

Batch Machine Mixing. — Batch machine mixing being the most satisfactory method of mixing concrete, very little fear need be entertained as to the thoroughness of the mix if the ingredients are all measured for each batch. It does not require many turns of a batch mixer to thoroughly mix concrete. About twenty-five turns of the mixer will be all that is necessary if the mix is a wet mix.

In mixing with a machine, the water should be measured for each batch, thus securing uniformity in this respect.

Continuous Mixer. — Continuous mixers have not found much favor for reinforced concrete. Practical tests under similar conditions on large work have resulted in the abandonment of the continuous mixer for the batch mixer.

The author has seen work executed with a continuous mixer where the contractor remixed by hand the concrete after it left the mixer; this he did on his account, recognizing the unsuitableness of the particular mixer for the work in hand.

Handling and Depositing Concrete.—With the actual handling of the concrete, the inspector has little to do, his duties being restricted to seeing that the quality of the work is maintained rather than the means used by the contractor to carry on the work.

However, as the inspector is interested in the pro-

gress of the work to see that the building shall be completed in the time agreed upon, the method of handling the materials may become of vital importance. For instance, the location of the apparatus used for mixing and hoisting the concrete should be such as to permit of depositing the material and leaving it set without being walked or traveled over, and at the same time not interfere with the progress of other work, when the building is of such a character or magnitude that several departments of work must proceed uninterruptedly after the construction has reached a certain stage.

It very frequently happens that by reason of the congestion surrounding the building, particularly in built-up sections of large cities, that the mixer and hoist must be placed in the building and a stair or elevator well used for the purpose. If the building is of some height, say eight stories or more, the lower floors are usually in a fair way to completion before the roof construction is finished; hence the introduction of the stairs in the well hole would be impossible when hoisting apparatus is still in use.

It is far preferable to have the apparatus for mixing and hoisting on the outside of the building. The usual method employed at the present time to raise concrete to the various floors is by means of a tilting bucket, of a capacity equal to that of the mixer, which is raised and lowered in a framework having guides on the sides similar to that of the ordinary hoisting elevator shaft. The bucket receives the concrete direct from the mixer, being shot into the

bucket by means of a wooden or metal chute. The bucket deposits the concrete at the top into a suitable hopper which is large enough to hold at least one, and preferably, several bucketfuls; the concrete is drawn off the hopper, directly into wheelbarrows or two-wheel concrete buggies, it being necessary to set the hopper some distance above the level of the floor upon which work is being performed, so that the concrete will flow into the wheelbarrows.

By this system no handling of the concrete is done until it reaches the floor, where work is being performed. Before the concrete is deposited into the forms, the inspector should see that the forms have been thoroughly water-soaked and cleaned of all shavings, saw-dust, etc., and that the metal reinforcement is in position. Of course, with the loose rod system, unless some method of wiring the parts together has been employed, all the metal cannot be set in position in advance of pouring the concrete, then the inspector must remain with the gangs doing the work, and be very diligent in watching to see if all the reinforcement is placed according to the detail drawings.

After the concrete is poured into the column and beam forms, it should be thoroughly flat spaded next to the forms so that it will make a smooth surface when the boards are removed. Ramming on top will not accomplish this result.

Warm Weather.—Concrete laid in warm weather should be wet twice daily, for the first week, to prevent premature drying out, thus weakening the concrete.

Cold Weather—Should it be found necessary to lay

concrete when the temperature is below 33° F., extra precautions must be taken. The water should be heated to about 100°. The stone and sand should be heated immediately before using, if covered with ice or snow. And the forms should be cleaned out by steam from a hose connected to the steam-boiler on the job; in this way any particles of ice are melted and the chill taken off the forms. Where the new concrete joins the old the edges should be thoroughly steamed. The freshly laid concrete should be covered with hay and artificial heat provided under the floor, taking care to close in temporarily exposed openings in the walls to keep the heat in.

Stopping Day's Work.—The methods employed to stop a day's work and leave the joint so as to make a satisfactory union with the new work performed later, is one about which authorities differ, but practice has shown that the two methods in common use have given equally satisfactory results.

In one method the day's work is stopped over the middle of a beam or girder in the direction of its length and in line with a column filling the entire beam and stopping the slab at the center line of the beam and leaving the slab reinforcing project at least one foot beyond the center line into the adjoining span. The stirrups from the beam on one side are left to project up into the slab of the next panel. Should the joint thus made be over the center of a girder, into which beams are framed, wooden stops to form pockets, where each beam frames into the girder, must be placed to extend one-

half the thickness of the girder and of a width equal to the width of the beams. In such cases the bars of the beams in the panel in advance of the one just cast must be placed before the concrete is poured, in order that the top bars may project into the concrete and thus anchor the two beams firmly together over the girder. If the rods of the beams are not long enough to run past the beam, there should be a tie-rod about five feet long with hook ends, placed over the girder, extending half-way into each beam, just at the level of the bottom of the slab. If these tie-rods are used, they should be set in the concrete and left to project into the adjoining span; then the bars of the beams need not be placed in the adjoining span until just before concreting.

In the second method, the day's work is stopped not over a beam or girder, but in the center of the span between columns cutting across the beams. This method is considered preferable to the former by some authorities, since it brings the joint in the concrete in a part of the floor where the shearing stress in the beams and slab is zero. The forces in the concrete at this point being altogether horizontal, similar in effect to those at the crown of an arch, the rods taking up all the tension. The cut-off in this method should be truly vertical, and since the rods in the beams and slab run continuously from bearing to bearing, one-half the length of the rods will be exposed until the work is started again. Care should be taken in making the stop, to introduce around the rods in the bottom of a beam,

bags or like material to prevent the liquid concrete from flowing under the rods into the part of the beam which is not to be poured with the other part. Should any very thin grout run through the stop, it should be cleaned out before the rest of the beams are concreted, since it is found that this thin layer will shrink away in time and peel off from the bottom of the beam, and is apt to give rise to the thought that the building is crumbling and about to disintegrate.

To make the joint water-tight, sheet metal strips bent V-shaped, with flanges projecting each side 3 inches, can be introduced in the joint of the slab, the bottom of the V to rest on the form and to be about 1½ inches high. This permits the secondary slab rods to run over the strip.

To stop the concrete, a one-inch board the thickness of the slab is beveled on the bottom edge and set in the copper strip, while slots are cut in the board from the bottom upwards to permit of the reinforcing cross rods to set down on top of the flanges of the copper strip. The wood strip is removed before starting the next run of concrete, and the concrete is permitted to fill over the copper strip.

If lintels project above the floor slab, they should be cast with the floor slab and not cast in two layers.

Columns should be poured to underside of deepest girder and left stand four hours before pouring the floor. This permits of the settlement of the concrete.

In joining new work to old the surface of the old work should be cleaned and thoroughly wet and the joint coated with a mixture of cement grout.

Protecting Finished Work.—In depositing concrete, the inspector should be diligent to watch that none of the liquid cement, which is apt to leak through the joints in the forms, runs down the face of any completed brick or stone work, as it is almost an impossibility to prevent permanent staining of walls should the cement drippings be permitted to harden on the walls. If, by accident, the cement should run down the face of a finished wall, the drippings should at once be scrubbed off with a copious supply of water before the cement starts to set. Vigilance on the part of the inspector in this matter will save much annoyance later in getting the work properly cleaned.

No cement should come in contact with the back of marble, limestones, and terra cotta. These should be painted on the back with a water-proof paint if the concrete is to come in contact with these materials while it is being poured; this frequently happens in the case of lintels, etc.

Water-proofing Concrete.—The use of reinforced concrete for retaining walls and roofs of underground vaults where the exclusion of water is necessary, also for tanks and reservoirs, renders imperative the making of the concrete water-tight. There are three general methods employed for this purpose: first, the method of applying as a coating on the face of the concrete some water-proof mixture or a coating of rich cement mortar. Second, adding to the concrete while mixing a substance such as hydrate of lime or a manufactured compound to make the mixture water-tight. Third, so grading the aggregate of the concrete to

make it dense and using a large proportion of cement to make a rich mixture.

With the last two methods, the work must be so performed that there will be no leakage at joints. It would be much better if the work could be made one continuous operation, but as this is usually impracticable except for small pieces of work, the joints must be made with great care; usually a tongued and grooved joint will answer the purpose, provided the old concrete is scrubbed clean and coated with a grout of cement before applying the fresh concrete.

A mixture of common muriatic acid and water in the proportion of one of acid to three of water should be used to wash clean the old surface of the joint, after which a copious supply of fresh water to wash away the effect of the acid should be used before applying the grout.

Authorities differ as to the best method of making absolutely water-tight concrete, but it is generally conceded that the concrete should be placed very wet and allowed to dry slowly, being protected from the direct rays of the sun. This can be accomplished by covering the concrete, in the case of vertical walls, with several thicknesses of muslin which is kept wet by sprinkling; usually a week's time is sufficient for this wetting.

Where the work to be water-proofed is of much magnitude, there is danger, should the concrete itself be made water-proof, that with the aging of the concrete shrinkage cracks will develop and thus nullify the water-tightness of the concrete by causing seams

through which the water can percolate; consequently when work is to be made water-tight, sufficient area of reinforcing bars should be used to counteract the shrinking of the concrete.

The inspector will find it one of his hardest duties to secure successful results in the matter of making concrete water-tight. For this reason some designers prefer the first system of water-proofing as it eliminates a great deal of the risk attached to the other two methods.

When patented compounds are used, it is best to follow the directions of the manufacturer, as much depends on experience to make a successful job.

Concrete Walls.—The building of reinforced concrete walls involves much more care than casting a floor; as stated under form work, to see that the forms are kept rigid, is of primary importance. In filling walls, if the wall is solid throughout its length and height, it may not be possible to fill an entire story at one operation, in which case it makes little difference whether the wall is filled up half way all around, or a section filled up the entire height of the story. As the concrete is usually dumped into the wall forms from the top, a long pole is necessary to churn the concrete as it is deposited, and a long-handle spade should be used to spade the concrete next to the form to push the large stones away from the forms and thus avoid a honeycombed appearance when the boards are removed. Care should be taken not to make the concrete too sloppy in filling high walls or columns, as the stones

are apt to settle to the bottom, forcing the cement and sand to the top, thus making laminations in the work. This would be visible after the concrete is dressed, should a pier or wall be left to set hard before it had been poured the full height. Great care is necessary to overcome this defect.

Further, the top of the concrete should be scraped off before applying the next run, as a thick film of inert material usually rises to the top of the concrete being without the stone weakens the column at this point.

Hollow Walls.—Sometimes it is necessary to form an air space in concrete walls; this can be accomplished economically by using a number of loose plank the thickness of the air space, about ten inches wide, and tapering them a little, oiling them and setting them vertically midway between the two sides of the form. If the space is to be in the middle, these plank are located about three inches apart, and are long enough to project above the concrete as it is poured. When the concrete has started to set, the planks are pulled up, leaving the lower end project into the concrete just placed; in this way the boards are removed, leaving an air space, and can be used over and over again to make similar hollow spaces in the wall. The three-inch space between the plank leaves the concrete flow from one face of the wall to the other and thus makes a tie.

Joints in Wall.—In stopping walls, in either a vertical or horizontal plane, a $3 \times 4''$ or $3 \times 6''$ piece, beveled on the two edges, should be set in the concrete so as to make a joint similar to the tongued and

grooved joints in boarding. The object of beveling the edges is to make the piece draw more easily.

Finishing Concrete.—With the use of concrete for exterior walls of building has come the desire to give the surface of the concrete a treatment that would overcome the lifeless muddy appearance inherent to the material. Various attempts have been made, all meeting with more or less success. Below we give some of the more common methods.

Coated Surface.—The most common, and at the same time cheapest, method, is to smooth off the rough parts of the concrete after the forms have been removed, and wash down the entire surface with a cement wash, similar to the manner of ordinary whitewashing. If a non-staining cement is used for this purpose, good appearance can be effected which will look uniform, but will lack that luster which is the life of a material, and is open to the objection that fine hair cracks are apt to appear. A good mixture is one of cement to two of fine sand mixed to the consistency of thick cream. The walls should be wetted with water before applying the wash.

Plastered Surface.—The method of applying a cement mortar plaster coat to the concrete after it has set is not to be recommended, as the unequal shrinkage of the two materials will cause scaling of the plaster coat. This is particularly noticeable in the case of walls above ground, which are subject to varying degrees of temperature.

Scrubbed and Tooled Surfaces.—By far the most successful treatment for the concrete is to scrub the

concrete, before it has obtained its final set, say within forty-eight hours after placing, by removing the forms and pouring water from a hose over the surface and removing the thin film of cement that is on the face of the wall by scrubbing with stiff brushes, exposing the stones. This gives a rough texture to the wall, and by the use of selected aggregate for the concrete, any desired effect can be obtained.

It has been found, however, that it is not always practicable to remove the forms so soon; hence, the concrete sets up hard, and the scrubbing has little effect on it. To meet this objection, tooling the concrete after it has set hard, using a stone cutter's pick, or better still, a pneumatic tool with points, is resorted to when this finish is desired. Some important work has been treated in this manner with highly satisfactory results.

In placing the concrete for work to be treated in this manner, it is important that seams do not occur in any surface that is not broken up by moldings, recessed joints and the like, as the seam or joint will show in a plain surface after tooling; hence, it is necessary to so mark the face of the concrete with "V" or half-round joints (not square) so that the work can be stopped at one of these lines.

To secure additional enrichment of the concrete, colored tile has been used with marked success; this is usually set in flush with the concrete surface. The best method to secure the tile in the concrete is to cast in the wall a sunk panel from 1 inch to 1½ inch deep, of an outline to suit the design. This panel is

then filled in at any convenient time with the tile bedded in cement mortar.

Concrete Block Walls.—The use of hollow concrete blocks for the walls of important structures has met with marked success, when the work has been intrusted to experienced persons.

Should the walls, built of blocks, be pierced with many openings, so that in effect the wall becomes a series of piers, it is necessary to fill the voids of the blocks solid with fine concrete or cement mortar so that the safe crushing strength of the concrete is not exceeded.

Excellent results have been obtained by the addition of longitudinal reinforcing rods, run in the hollow spaces of the block from floor to floor, similar to the rods in a column, one-quarter inch wire ties being bedded in every other joint between courses; this virtually makes a concrete column of the blocks, since the core is filled with monolithic concrete. The rods are placed in the block after the pier is built the height of the story, and the cement grout is poured from the top the full height. Care must be taken to put collars around the base of the pier and for about one-third the height to prevent the bursting of the walls of the blocks by the hydrostatic pressure of the liquid concrete. Of course, the blocks are laid up with a full mortar joint and allowed to set before filling.

The manufacture of blocks is a subject that requires a great deal of care. Unfortunately the state of the art has not arrived at a standard to compare with

monolithic concrete; hence the inspector will need to exercise the greatest diligence should he be called upon to pass upon them. As the various machines on the market mold the blocks in different manners, it is necessary for the inspector to become familiar with the operation of the machine from which the blocks are made.

The processes of manufacture of the blocks can be grouped under three methods—hand-tamped, hydraulic-pressed, and the shaking process.

In general the strength of the block is proportioned to its density, hence the process that makes the most dense concrete makes the strongest block; for this reason blocks made in hydraulic presses and by the shaking process are superior to the hand-tamped.

The concrete used in the blocks should not contain a very coarse aggregate for the reason that it is hard to secure a uniform face; it is usual to use a mixture composed of one part of cement to two or three parts of sand or stone screenings. The latter material usually makes the strongest block.

The same precautions used for making concrete in bulk should be taken in making concrete for blocks; in fact, greater care is needed in proportioning the materials, and the treatment the block receives after casting is of utmost importance. Usually a very dry mix is necessary in making blocks, so that they can be removed from the mold at once; hence, the blocks must be sprinkled with water after making. This process causes the blocks, as a rule, to be porous and absorb much moisture. Hence some method should

be used to waterproof the concrete used in making blocks. The curing of the block (that is, sprinkling daily with water), usually takes ten to fifteen days with a hand-tamped block, while with a hydraulic pressed block one week is sufficient. Some manufacturers advocate steam curing; this permits the block to be used in a much shorter time, usually in about twenty-four hours, but as the effect of steam curing is not absolutely known, the advisability of employing this method for curing may be questioned.

In the few remarks on the subject of blocks, it is not our intention to go thoroughly into the manufacture of them, as that is a subject by itself, but it has been our aim to assist the inspector to right conclusions as to the underlying facts relating to block construction.

Sand-Molded Work.—Where architectural members, such as columns, ornamental caps, keystones, etc., are required by the design, very successful results can be obtained by having the ornamental parts cast separately in sand molds and setting the finished parts in the wood forms at the building, and casting them in solid with the monolithic work. In this way there is no danger of the work not coming out satisfactorily, as each piece can be inspected before placing in the wall. Special designs can be very readily made up in this manner, and where there is a repetition of the same design, one model will suffice for the entire lot.

Cage Construction.—The use of concrete columns or piers for the supporting elements of the exterior of

buildings has come into general practice; so that we frequently find a building designed with a concrete framework or cage and the panels filled in with some other material, such as brick, leaving the concrete columns exposed to view on the exterior. This form of construction is applicable to party or division walls and to walls where a paneled effect is desired. Foi highly ornamental buildings, the columns can be covered with a veneer of four or eight inches of brick or ornamental terra cotta, thus casing the structural part of the building in the same manner as in steel frame construction. When the columns are so covered, iron ties should be built in the concrete to secure the brick or terra cotta to the concrete; also, grooves should be left in the sides of the columns for the brick to fit into.

Cement Stairs.—The use of reinforced concrete for the construction of stairs makes it possible to build any type of stairway, and at the same time make it fireproof; in fact, where a stairway in a non-fireproof building is to be built fire-proof, this construction may be used and will give results not obtainable in other methods of construction without much greater expense. In the design of stairs, it frequently happens that where landings occur, no support can be obtained at these points; in such cases reinforced concrete can be used with great success; whether the stairs are curved or straight, it makes little difference, as the rods can be bent to suit any condition, and, of course, the concrete can be molded in any shape.

If the stairs are of the ordinary factory type, they

are usually finished with a top coat of cement and sand for the treads and risers. Where a rich finish is desired, marble treads and risers are placed over the concrete; these should be solidly bedded and secured in position. Provision for securing the railings should be made by building in bolts or anchors during the construction of the stairs.

The method of building straight flights of stairs usually consists in considering each flight as an inclined beam having the rods near the soffit of the stairs, running from bottom to top; where quarter- or half-paces occur, there is usually a beam to support the flights of stairs and edge of pace, the pace being treated as a slab with rods run in the shortest direction. Sometimes it is necessary to run an outside string of concrete to support the stairs. This acts as a beam and should be so figured, making the rods continuous from bottom to top, placed near the bottom of the string.

Roof Surfaces.—The finished covering of a concrete roof may be of various materials. The mere finishing up of the concrete so as to make a smooth surface is not recommended, due to the fact that should the concrete of itself be watertight, this quality may at some time be nullified by the occurrence of shrinkage cracks, which would permit water to percolate through the roof. However, if a sufficient number of shrinkage joints are introduced and these are made water-tight by the introduction of a trough-shaped strip of copper or lead, which will take up the contraction and expansion, the cracks may be avoided. Frequently a three-

quarter inch surface of cement and sand or grits in the proportions of one part of cement to one-half or two parts of sand is laid directly on the concrete before it takes its final set. This forms the final surface for the concrete and can be used for porch floors, provided the necessary precautions are taken in providing water-tight expansion joints in the concrete as mentioned above.

A very satisfactory and common method of covering a concrete roof is to lay over the slab after it has been smoothed off a regular four-ply felt and slag or gravel roof; the gussets are usually formed over the slab by using concrete, having cinder instead of stone aggregate to lighten the weight, as it frequently happens that the gussets are very large.

The most durable roof covering for flat surfaces is tile embedded in asphalt; this tile consists of flat rectangular terra cotta tile about 1¼ inches thick, bedded in hot asphalt, laid over the four thicknesses of felt mentioned above. The joints between the tiles are filled with liquid pitch or asphalt. Small squares of roofing slate are also used in place of the tile and make an excellent wearing surface.

Whatever the roof covering, the inspector should see that the concrete is thoroughly graded to eave boxes before any of the covering is laid, as the base upon which the covering is laid must be made to drain thoroughly if the finished roof is to be successful.

Where concrete walls, etc., project above the roof proper, reglets must be left in the concrete to insert the edge of the flashing; these reglets can be made

by introducing a strip of wood in the forms, three-quarter inch high by from one to two inches deep, according to the thickness of the wall, the strip being taken out when the forms are removed and the flashing keyed into the reglets and cemented with rubber cement.

Top Coating of Floors.—The most satisfactory method of laying a cement top coating over cement floors is to first lay a concrete base, not less than two inches thick, composed of one part of cement, two parts of sand and four parts of stone or clean cinders; over this base the top coat is laid in the same manner as the top coat for a sidewalk, care being taken not to leave the concrete base set before laying the top coat. The advantage of this method is that should there be any reason for removing a block or section of the finished floor, it can be done without injuring the reinforced concrete slab, also the two-inch cinder base forms a most excellent space for the running of gas pipes, electric conduits, etc., without having them exposed on the ceilings below.

The method of laying a one-inch top coat directly on the reinforced concrete slab, before the latter has set, is not an entirely satisfactory method, for should the top coat become in any manner damaged, it cannot be removed and relaid so as to unite perfectly with the old concrete. There are some preparations on the market which are supposed to accomplish this result, and, no doubt, if used properly, give satisfaction.

Filling Between Sleepers.—In laying a finished wood

floor over reinforced concrete, it is necessary to lay 2×3 or 3×4 inch sleepers over the concrete slab and fill in between with cinder concrete in the proportions of 1:3:6; this work is usually done just before the wood floor is laid, leaving sufficient time before laying the flooring boards to permit the cinder concrete to dry out. The best manner of holding the sleepers in place is to drive 40d nails in the sides of the sleepers at intervals of three feet, on alternate sides of the sleepers; these nails key with the concrete, thus preventing the loosening of the sleeper in the concrete when it shrinks; the method of beveling the sleepers does not overcome the loosening when the wood shrinks.

General Conclusions.—It has been the intention in this little volume to cover the principal points upon which information is likely to be wanted by an inspector, at the same time the authors are fully aware that many questions arise during a building operation that cannot be solved by reference to printed instructions. Experience is the best teacher, and where possible an inspector should permit a contractor to employ those methods which previous use has demonstrated to be the proper practice.

Where a guarantee accompanies a piece of work, it is usually better to allow the contractor to use the method he deems fit to accomplish the end sought than to insist on a method which being no better, places the responsibility of the successful issue of the work upon the inspector, and hence upon the party he represents.

When a contractor deliberately attempts to use a method which is contrary to common practice in order to cheapen the work, or through ignorance, it is the inspector's duty to stop the work until the matter is passed upon by his superiors.

One of the best qualifications for a successful superintendent or inspector, after a thorough knowledge of the subject, is constant vigilance. Do not take for granted anything, obtain your facts first hand and be sure you are right before condemning a piece of work, and then take a firm stand.

Further, a daily record of the work as it progresses should be kept. A very satisfactory way to keep such a record is to have a diary and enter the day's run in it. This is simplified by dividing the plan of the building into panels corresponding to the bays of the building and numbering them consecutively. This key can be used when referring to a section of work, and is indispensable when the time comes for striking the forms, since then the panels that have obtained the requisite age can readily be picked out and the work of removing the forms of these only proceed, while the forms under the part not ready to pull can remain.

In conclusion, the inspector should constantly keep in mind that reinforced concrete is a composite construction, that it is essential to have not only good concrete but to have a sufficient quantity of reinforcing steel, and whenever in doubt, it is always better to err on the side of safety and insert the reinforcement where common sense dictates, even

though not called for by the drawings, as sometimes it is difficult to show by a drawing just where every piece of steel should go, as the days run, due to rain or some unavoidable accident, may make a joint where it is least expected.

APPENDIX

Rectangular Beams.—Experiments have shown that in the strength of rectangular reinforced concrete beams, with not over one per cent of reinforcement, the steel can be considered as being the factor limiting the strength of the beam, provided stirrups and other means are used to prevent failure by diagonal tension; and that for practical purposes the resisting moment of such a beam may be considered as being equal to the moment of the steel with reference to the center of action of the concrete. See Bulletin No. 14, Vol. 3, of the University of Illinois.

Expressed by the formula, we have $M_R = A \times .85d \times 16{,}000$, in which M_R is the resisting moment of the beam, A = the area of the steel, d = the distance from the center of action of the steel to the top of the concrete, and 16,000 being the safe unit stress on the steel. Simplifying the formula, we get $M_R = 13{,}600\ A\ d$, all dimensions being in inches.

Slabs are usually considered as rectangular beams spanning from beam to beam, and a section one foot wide is usually used in figuring the sizes of the concrete and steel.

The following diagrams, Plates 1 and 2, have been prepared in order to facilitate the designing of slabs. The total load being assumed, the diagrams give the proper area of steel for various thicknesses of slabs on various spans, based on unit stresses, as ıequired by the Philadelphia Building Regulations.

One can readily find the live load that a slab will carry by deducting the weight of the slab and the finished floor from the load shown on the left hand edge of the diagram, the weight of the reinforced concrete being assumed as 150 pounds per cubic foot.

Two sets of diagrams are given, one set calculated on the basis of simple beams, bending moment $\frac{WL}{8}$, and the other set on the basis of restrained beams, bending moment $\frac{WL}{10}$.

Below are given formulæ for strength of rectangular beams or slabs, based on various percentages of steel, and beams considered as simply supported at the ends. Calculated in accordance with the Philadelphia requirements.

W = load in pounds per running foot;
b = breadth of beam in inches;
d = depth to center of action of steel in inches;
L = span in feet;
P = percentage of steel to area of concrete above center of steel to top of beam.

When $P = .5\%$ then $W = 48\frac{bd^2}{L^2}$;

When	$P=.6\%$	then	$W=56\dfrac{bd^2}{L^2}$;
"	$P=.7\%$	"	$W=59\dfrac{bd^2}{L^2}$;
"	$P=.8\%$	"	$W=62\dfrac{bd^2}{L^2}$;
"	$P=.9\%$	"	$W=64.5\dfrac{bd^2}{L^2}$;
"	$P=1\%$	"	$W=67\dfrac{bd^2}{L^2}$.

Example. Find the total load per square foot that can be carried by a 4-inch slab reinforced with .8% of steel per running foot on a 5-foot clear span.

Answer:

$$W=62\times\frac{12\times3^2}{5^2}=62\times\frac{108}{25}=266.6 \text{ pounds.}$$

From this must be taken the weight of slab and floor finish to obtain the live load.

Note. If total load carried by the beam is desired, use L instead of L^2 in the formula.

These formulæ are based on the stress in concrete not exceeding 600 pounds per square inch and tension in steel of 16,000 pounds per square inch, with a ratio of the coefficients of elasticity, concrete to steel, of 1 to 12, and give a carrying capacity for a beam less than Prof. Talbot's formula by approximately 15%.

T-Beams.—Tests on full-size T-beams made by the authors have likewise demonstrated that for all practical purposes the resisting moment of a properly reinforced T-beam is equal to 16,000 times the area of the steel, multiplied by the distance from the center of the slab to the center of action of the steel, all dimensions being taken in inches. See *The Journal of the Franklin Institute*, January, 1906.

TABLE I

TABLE FOR DETERMINING THE WIDTH OF FLANGES FOR T-BEAMS OF VARIOUS DEPTHS AND SLAB THICKNESSES IN TERMS OF STEEL AREAS.

D = depth of beam below slab
W = total width of flange in inches.
A = area of steel in bottom of beam.

3-inch Slab.		4-inch Slab.		5-inch Slab.		6-inch Slab.	
D	*W*	*D*	*W*	*D*	*W*	*D*	*W*
12″	14.9*A*	12″	13.4*A*	....	...	....	...
14″	13.6*A*	14″	12.0*A*	14″	10.8*A*	14″	11.5*A*
16″	12.8*A*	16″	10.8*A*	16″	9.8*A*	16″	9.0*A*
18″	12.0*A*	18″	10.0*A*	18″	8.9*A*	18″	8.2*A*
20″	11.7*A*	20″	9.6*A*	20″	8.4*A*	20″	7.7*A*
22″	11.2*A*	22″	9.3*A*	22″	8.0*A*	22″	7.3*A*
24″	10.8*A*	24″	9.0*A*	24″	7.7*A*	24″	6.9*A*
26″	10.8*A*	26″	8.7*A*	26″	7.4*A*	26″	6.7*A*
28″	10.4*A*	28″	8.4*A*	28″	7.2*A*	28″	6.5*A*
30″	10.4*A*	30″	8.4*A*	30″	7.1*A*	30″	6.3*A*
....	.....	....	....	32″	7.0*A*	32″	6.0*A*
....	.....	....	....	34″	6.9*A*	34″	6.0*A*
....	....	....	....	36″	6.7*A*	36″	5.9*A*

Note.—The area of the steel is to be taken from the diagram of strength of T-beams.

Expressed by formula, we have M_R equals 16,000 Ad', in which A equals area of steel, and d' equals distance from center of slab to center of action of the steel.

Conversely, to find the area of steel when the bending moment is given, the formula becomes

$$A = \frac{M}{16{,}000d'}.$$

This is the formula upon which the following diagrams, Plates 3, 4, 5, and 6, are based. The center of action of the steel is considered as being three inches from the bottom of the beam in all instances, also the depths of the beams indicated in the diagrams are the total vertical distances of the ribs below the slabs.

Rectangular Columns.—In designing rectangular columns, there are two methods in general use—to allow a specified unit stress on the concrete, neglecting the strengthening effect of the vertical rods; and to consider both concrete and rods as taking their proportion of the load depending upon their relative coefficients of elasticity. In Philadelphia, the former method is used, and just sufficient number of rods, usually four, are used to hold the concrete together and take care of tension in the column, should any exist.

INCREASE IN STRENGTH OF COLUMNS PER SQUARE INCH FOR VARIOUS PERCENTAGES OF STEEL—RATIO 1 TO 12.

WORKING STRESS ON CONCRETE ASSUMED AT 500 POUNDS PER SQUARE INCH

FORMULA

$$W = A(C + Cn \times \text{per cent of steel}),$$

in which W = total safe load;

A = area of column;

C = allowable unit stress on the concrete;

n = ratio of the coefficients of elasticity.

EXAMPLE. Find the load that can be carried by a 16×16-inch column with 1% reinforcement.

Answer:

$$W = 256(500 + 500 \times 12 \times .01);$$

$$W = 256(500 + 60);$$

$$W = 256 \times 560 = 143{,}360 \text{ pounds}.$$

Table II

BASED ON PRECEDING FORMULA

Percentage of Reinforcement.	Safe Loads per Sq. In. in Lbs.	Percentage of Reinforcement.	Safe Loads per Sq. In. in Lbs.
.1%	506	1%	560
.2	512	1.5	590
.3	518	2	620
.4	524	2.5	650
.5	530	3	680
.6	536	3.5	710
.7	542	4	740
.8	548	4.5	770
.9	554	5	800

Table III

STRENGTH OF PARTIALLY REINFORCED CONCRETE COLUMNS

WORKING STRESS ON CONCRETE 500 POUNDS PER SQUARE INCH

Size.	Area.	Total Safe Loads in Lbs.	Size.	Area.	Total Safe Loads in Lbs.
8×8	64	32,000	18×18	324	162,000
9×9	81	40,500	19×19	361	180,500
10×10	100	50,000	20×20	400	200,000
11×11	121	60,500	21×21	441	220,500
12×12	144	72,000	22×22	484	242,000
13×13	169	84,500	23×23	529	264,500
14×14	196	98,000	24×24	576	288,000
15×15	225	112,500	25×25	625	312,500
16×16	256	128,000	26×26	676	338,000
17×17	289	144,500	27×27	729	364,500

TABLE IV

WEIGHTS AND AREAS OF SQUARE AND ROUND BARS

Thickness or Diameter in Inches.	Weight of Square Bar 1 Ft. Long.	Weight of Round Bar 1 Ft. Long.	Area of Square Bar in Sq. Ins.	Area of Round Bar in Sq. Ins.
$\frac{1}{4}$	.213	.167	.0625	.0491
$\frac{5}{16}$	.332	.261	.0977	.0767
$\frac{3}{8}$	.478	.376	.1406	.1104
$\frac{7}{16}$	.651	.511	.1914	.1503
$\frac{1}{2}$	.850	.668	.2500	.1963
$\frac{9}{16}$	1.076	.845	.3164	.2485
$\frac{5}{8}$	1.328	1.043	.3906	.3068
$\frac{11}{16}$	1.607	1.262	.4727	.3712
$\frac{3}{4}$	1.913	1.502	.5625	.4418
$\frac{13}{16}$	2.245	1.763	.6602	.5185
$\frac{7}{8}$	2.603	2.044	.7656	.6013
$\frac{15}{16}$	2.989	2.347	.8789	.6903
1	3.400	2.670	1.0000	.7854
$\frac{1}{16}$	3.838	3.014	1.1289	.8866
$\frac{1}{8}$	4.303	3.379	1.2656	.9940
$\frac{3}{16}$	4.795	3.766	1.4102	1.1075
$\frac{1}{4}$	5.312	4.173	1.5625	1.2272
$\frac{5}{16}$	5.857	4.600	1.7227	1.3530
$\frac{3}{8}$	6.428	5.049	1.8906	1.4849
$\frac{7}{16}$	7.026	5.518	2.0664	1.6230
$\frac{1}{2}$	7.650	6.008	2.2500	1.7671

Table V

INGREDIENTS IN ONE CUBIC YARD OF CONCRETE CALCULATED BY FULLER'S RULE

Proportions.	Cement, Barrels.	Sand, Cubic Yards.	Stone, Cubic Yards.
1-2 -4	1.57	0.44	0.88
1-2 -5	1.37	0.38	0.96
1-2½-5	1.29	0.45	0.90
1-3 -5	1.22	0.51	0.85
1-3 -6	1.1	0.46	0.92
1-4 -8	0.85	0.49	0.95

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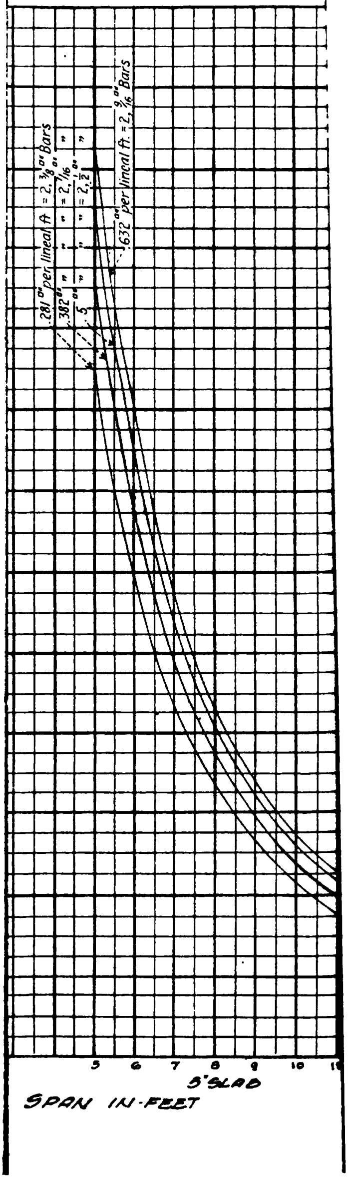
PLATE I



.281 □" per lineal ft = 2, 3/8 □" Bars
.382 □" " " " = 2, 7/16 □" "
.5 □" " " " = 2, 1/2 □" "
.632 □" per lineal ft. = 2, 9/16 □" Bars
5 6 7 8 9 10 11
5" SLAB
SPAN IN-FEET

Sle
So
Sta
Ste
Sti
Sto
Sto
Su

Sy

Vo
Wa

Wa

Sle
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PLATE IV

DIAGRAM OF THE STRENGTH OF T-BEAMS

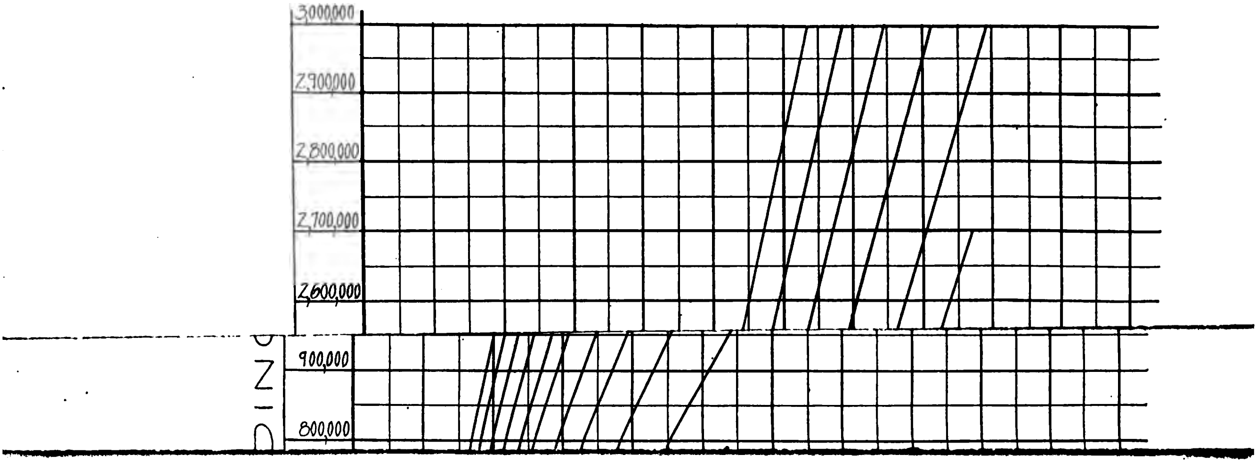


PLATE V

Diagram of the Strength of T-Beams

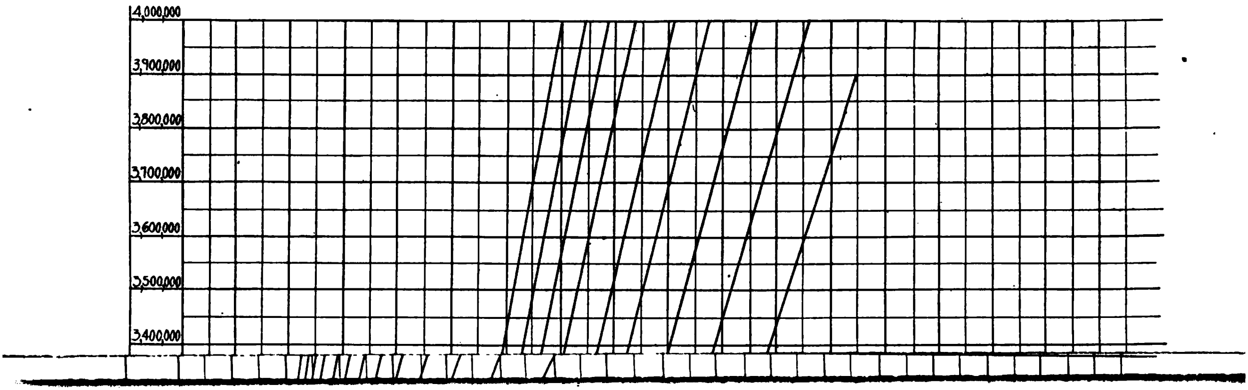
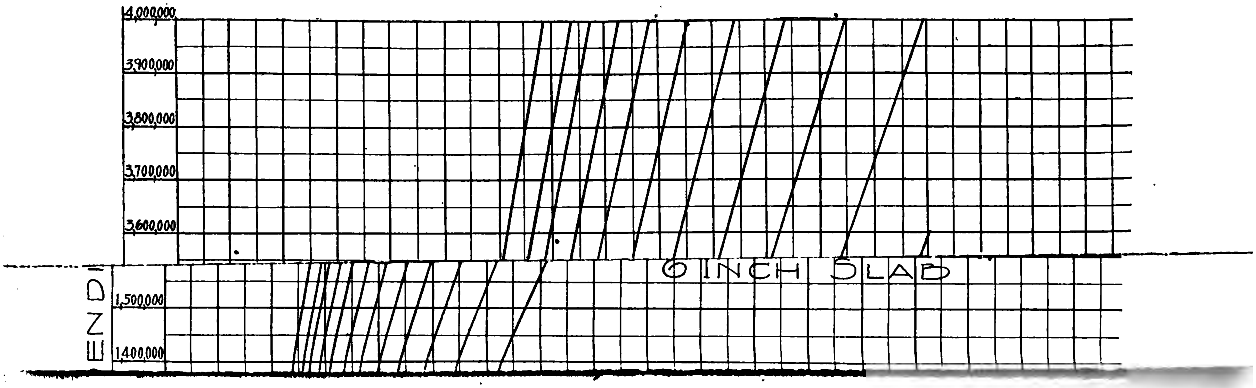


PLATE VI

Diagram of the Strengh of T-Beams



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